

ASPECTS OF THE BIOLOGY OF THE LIZARDS OF THE WHITE SANDS, NEW MEXICO

By JAMES R. DIXON¹

ABSTRACT: On the White Sands diurnal cycles of *Uta*, *Sceloporus* and *Holbrookia* involved two daily activity periods, the first between 9 to 11 AM, the second 3 to 5 PM. *Cnemidophorus* have one diurnal activity period, 9 to 12 AM. *Holbrookia* and *Sceloporus* appear to have similar reproductive cycles and produce one egg clutch each season, while *Uta* produces at least two egg clutches during the same period. *Cnemidophorus* seems to have a long incubation period, with only one egg clutch each season. *Uta* and *Sceloporus* appear to maintain a body temperature between 34 to 36°C, *Holbrookia* between 35 to 39°C, and *Cnemidophorus* between 37 to 39°C. The *Holbrookia* population appears to have diverged most significantly from the parental stock, followed by *Cnemidophorus*, *Sceloporus*, and *Uta*.

INTRODUCTION

The White Sands of New Mexico are located in the south central part of the state, approximately 88 kilometers northeast of Las Cruces and 24 kilometers west-southwest of Alamogordo, on U.S. Highway 70-82. The sands represent a large, uniform environment, probably of pre-Pleistocene origin, and support several endemic plants, invertebrates, and vertebrates. Most of the populations on the dunes differ strikingly in color from allied populations from immediately adjacent situations and offer an interesting natural experiment in speciation.

The organisms inhabiting the white sands have been studied by many people, notably Benson (1933), mammals; Bugbee (1942), invertebrates; Emerson (1935), plants; and Smith (1943), Lowe and Norris (1956), Ruthven (1907), reptiles. However, no one has attempted to study the lizards in their natural environment except Dr. Charles H. Lowe, Jr., and party in the late 1940's and early 1950's (Lowe, pers. comm.). The present study was initiated in June 1963, and was continued during the summer months of 1964 and 1965. The extreme heat, absence of shade, and frequent spring wind storms made field work difficult, and efforts to maintain a daytime vigil over certain study areas within the white sands was almost impossible, particularly in areas of adobe soil.

Three species of lizards occur abundantly on the dunes, and the food habits of these forms were discussed by Dixon and Medica (1966), and no mention of food preferences is made in the present paper. Lizards were cap-

¹Curator of Herpetology, Los Angeles County Museum of Natural History, Los Angeles.

tured either by hand or killed by a 22 caliber dust shot. All temperature data were obtained with a Schultheis thermometer, calibrated from 0 to 50°C. A total of 440 lizard's temperatures was taken.

GEOLOGICAL HISTORY OF BASIN

Herrick (1904) gives an accurate account of the geologic history of the basin and provides several interesting hypotheses involving its past.

The essence of Herrick's paper is that intensive faulting in late Cretaceous or early Tertiary reduced the Tularosa Basin to its present level, though some dislocations may have occurred at a later date. He believes that a river of considerable magnitude occupied the valley and flowed southwestward to enter the Rio Grande Valley (and river) in the vicinity of El Paso. This ancient river was later diverted, probably westward, by a great sheet of "mal pais" introduced by basaltic overflows in the Tertiary. This large lava mass essentially cut off the flow of water from the north end of the basin and blocked it completely. A long period of periodic rainfall and intermittent aridity assisted in silting up the outlet towards El Paso, forming a large ancient lake that is now recognized as Lake Lucero.

Herrick estimated the size of the ancient lake as 1600 to 1800 square miles. The old shore lines are now buried under the talus from the mountains. Some of the talus deposits are 800 feet thick at the present time. Erosion has exposed the remnants of old lake benches along the northwest border of the basin and these are considered the early margins of the lake.

The present lake bed has been examined to a depth of 200 feet, and consists of successional layers of gypsum and saline beds intercalated in gypsiferous marls. The San Andres Mountains to the west and the Sacramento Mountains to the east are layered with Cretaceous sandstone and shale, and with Permian soft gypsiferous shales and sandstones. Weathering of the layers has probably produced the present sediments occupying the lake bed. The majority of the springs that feed the basin are only a few hundred yards long in most cases, and are high in dissolved salt content. Mal Pais Spring contains 15 per cent dissolved salt, Salt Creek 35 per cent, Lost River 7 per cent, and the Tularosa River 7.8 per cent.

At the present time, as in the historic past, percolating water from summer rains and melting winter snow carries tons of dissolved gypsum and salt from the mountains into the lake bed. The warm spring and summer winds evaporate the water and deposit extensive beds of pure gypsum on the surface. The wind picks up the gypsum particles and deposits them to the northeast, the direction of the prevailing winds. These deposits have formed extensive dunes that are now under the jurisdiction of the U. S. Park Service, the White Sands National Monument.

The white sand dunes are continually changing their shape and moving to the northeast at the rate of a few centimeters a year. The older dunes lying

to the southwest have become stabilized with vegetation. These dunes are now encrusted with a mixture of adobe soils and gypsum. The present active dunes occupy some 444 square kilometers of the basin, and may rise as high as 10 meters from the basin floor. They are composed of almost pure gypsum (hydrous calcium sulphate) and are generally damp within a few centimeters of the surface. The water table is high most of the year, usually within one meter of the surface of the depressions that lie between the dunes.

VEGETATION AND CLIMATE

The adobe soils surrounding the dunes support 13 species of grasses, the common ones being three awn (*Aristida* spp.), drop seed (*Sporobolus* sp.), muhly (*Muhlenbergia* sp.), gramma (*Bouteloua* sp.), alkali (*Distichlis* sp.), burrograss (*Scleropogon* sp.), and sand bunchgrass (*Oryzopsis* sp.). Some of the larger trees and shrubs are cottonwood (*Populus wislizeni*), mesquite (*Prosopis glandulosa*), creosote bush (*Larrea tridentata*), squawbush (*Rhus trilobata*), rabbitbush (*Chrysothamnus pulchellus*), saltbush (*Atriplex canescens*), and shrubby pennyroyal (*Poliomintha incana*). The old stabilized dunes that lie to the southwest are slowly being covered by the latter vegetation (Fig. 1). A large alkali flat lies to the west of the major dune area and is essentially void of vegetation with the exception of two genera, burroweed (*Allenrolfea occidentalis*) and sand verbena (*Abronia angustifolia*).



Figure 1. View of stabilized gypsum dunes along the southwest edge of the White Sands National Monument. Some of the reptiles found in this area are: *Cnemidophorus inornatus*, *Cnemidophorus neomexicanus*, *Crotaphytus collaris*, *Sceloporus undulatus*, *Sceloporus magister*, *Phrynosoma modestum*, *Phrynosoma cornutum*, *Uta stansburiana*, *Crotalus atrox*, *Crotalus viridis*, and *Pituophis melanoleucus*.

The southern edge of the dunes is slowly becoming stabilized and one may find several stages of plant succession taking place. Some of the more conspicuous plants are *Atriplex*, *Rhus*, *Chrysothamnus*, and *Populus*.



Figure 2. View of the central area of the White Sands looking northwest. The arrow points to a single cottonwood protruding from the top of a dune. The depression between the dunes on the left is almost void of vegetation while the depression in the center contains a fair amount of plant cover.

The active dunes are lacking in vegetative cover with the exception of an occasional yucca (*Yucca elata*) and cottonwood (*P. wislizeni*) rising from the top of a dune (Fig. 2). The depressions between the dunes frequently have a scattering cover of sand verbena (*Phyla incisa*), primrose (*Anogra gypsophila*), sand bunchgrass (*O. hymenoides*), mormon tea (*Ephedra torreyana*), drop seed (*Sporobolus* sp.), four o'clock (*Abronia angustifolia*), yucca (*Y. elata*), and rabbitbush (*C. pulchellus*). The depressions closest to the edge of the dunes have dense vegetative cover, while those near the center of the dunes are sparse (Fig. 3). An excellent account of the plants of the white sands is given by Emerson (1935).

The average summer (June, July, August) air temperature of the dunes (six feet above the ground) ranges from 16°C at night to 38°C during the day. The average winter (December, January, February) air temperatures are 11°C during the day and -6°C at night. The summer temperatures of the adobe and gypsum soils vary with the amount of wind, moisture, and cloud cover. However, the adobe soil is generally warmer than the gypsum soils (Fig. 4).



Figure 3. View of a depression between the dunes in the center of the White Sands. The dark plant in the foreground is sand verbena, the scattered clumps of grass are single stands of sand bunchgrass, and the large plants in the background are *Ephedra* (mormon tea) and rabbitbush.

NATURAL HISTORY OF THE LIZARDS

Sceloporus undulatus: The western fence lizard is common in the depressions between the dunes wherever rabbitbush, yucca, mormon tea, and sand bunchgrass are present. The light color phase of this species found in the center of the active dune area is occasionally found along the edges of the dunes in adobe soil. However, none was found farther than 10 meters away from a gypsum dune. The normal dark phase found on the adobe soil is present in the stabilized dunes where the dunes have become encrusted with adobe dust. They have also been found in adobe depressions within the gypsum dunes. The latter areas have recently been captured by the movement of the dunes to the northeast, but have not become completely covered by the sand.

These lizards are never found more than a meter or two from plant cover. The majority of individuals were taken from the basal areas of rabbitbush, yucca, sand bunchgrass, or from the lower branches of rabbitbush and mormon tea. The lizards were reluctant to leave plant cover, even when pursued by hand.

There are usually twice as many males as females present at all times during June, July, and August. Both sexes are active from about 8 AM to 6 PM

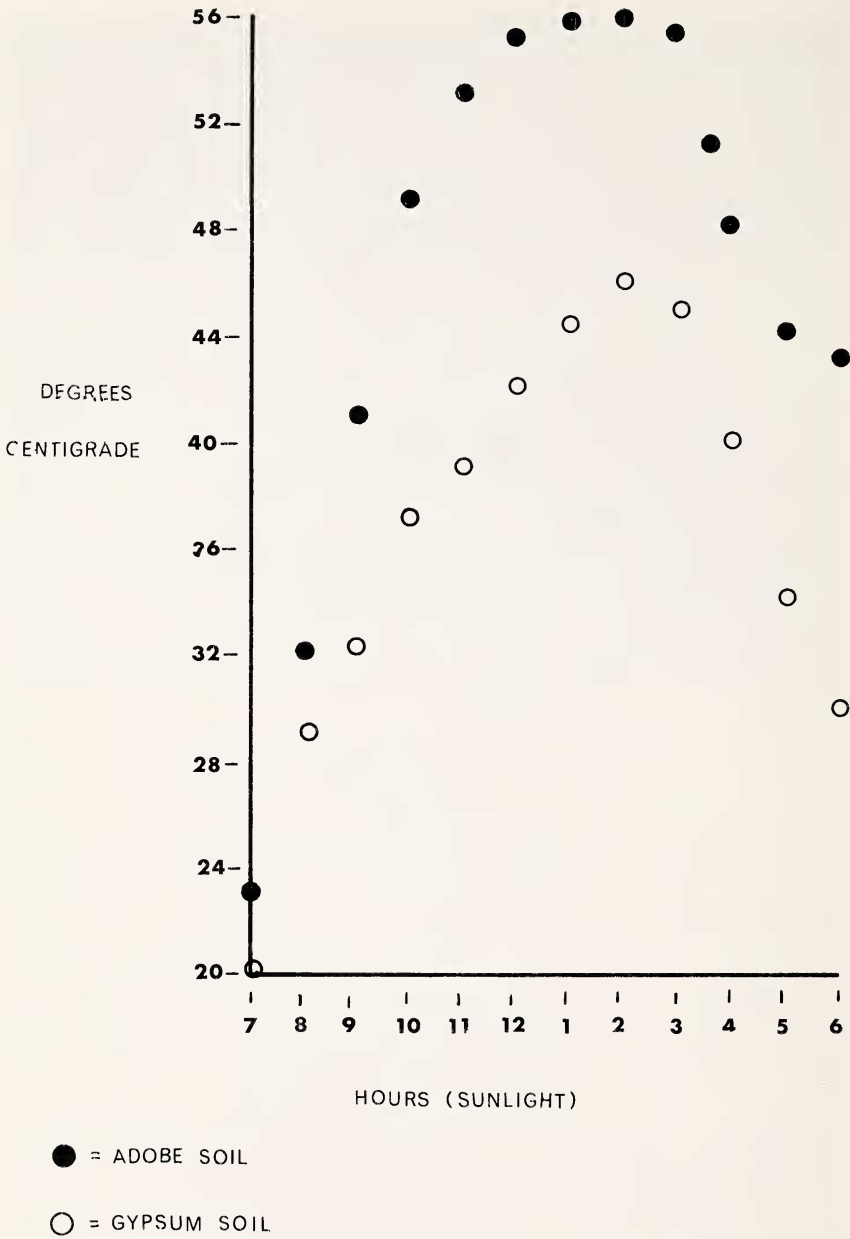
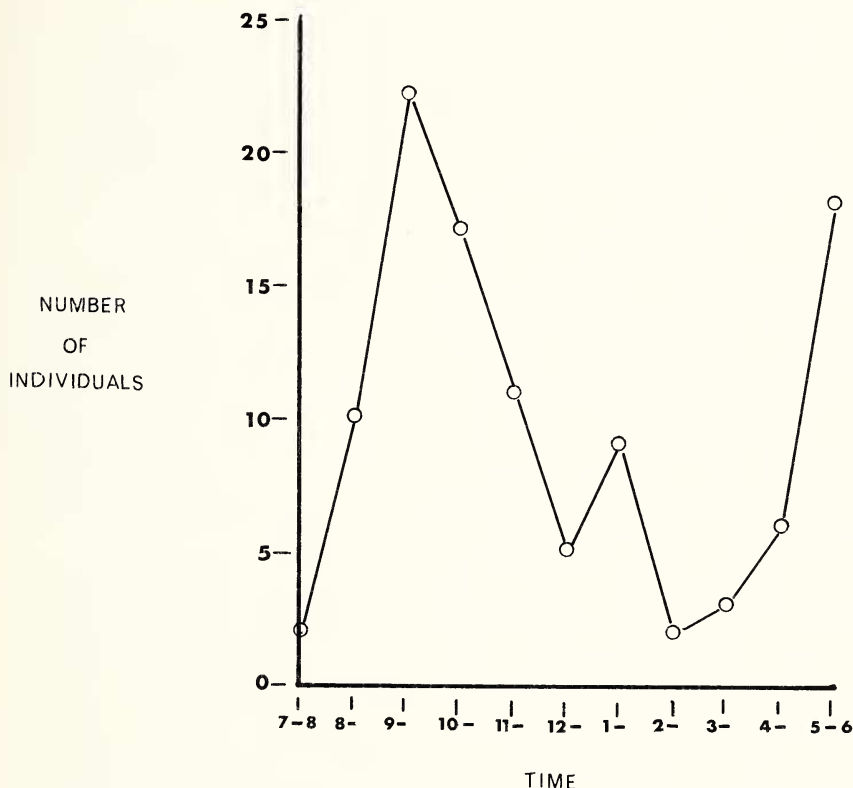


Figure 4. Typical daytime adobe and gypsum soil temperatures during mid-July, vicinity of White Sands National Monument headquarters, New Mexico.

on a normal sunny day. The majority of individuals were observed between 9 and 11 AM, the least number at 7 AM and 2 PM. There appeared to be a late period of activity between 4 and 6 PM (Fig. 5). The latter activity appears to be correlated to the heat holding capacity of the sand beneath dense clumps of rabbitbush. The surrounding soil temperature was 28°C while that below the shrubs was 35°C at 5:30 PM.



SCELOPORUS UNDULATUS

Figure 5. Vertical axis represents the average number of individuals of *Sceloporus undulatus* observed each hour on the White Sands during the summer months of 1963-65, horizontal axis indicates hourly intervals during the same period.

Gravid females were taken from June 12 through July 16. A few hatchlings were observed on August 16, and became increasingly more abundant in the population during late August and early September. Gravid females dis-

played bright colors on the dorsum and tail. The mid-dorsal and lateral light stripes became progressively more yellow to yellowish-orange from late June to mid-July. Shortly after egg deposition, the colors faded back to their normal gray to light buff color. This color change may be attributed to the presence of fat deposits during pregnancy and/or to a hormonal mechanism that is induced while the females are carrying the eggs. These bright colors may also tend to warn the males that the female is gravid and copulation has already been achieved.

Body temperature and associated soil and air temperatures were taken for 140 individuals during June, July, and August. The lizards were either captured by hand or shot. An analysis of cloacal temperatures resulting from the two capture methods indicated that there was no significant difference between the two methods. The body temperature was found to be higher than the ambient temperatures, except during the hottest part of the day (2 to 4 PM). The body temperature varied from 32.3°C to 37.2°C between the hours of 8 AM and 6 PM. The majority of individuals were observed sunning themselves between the hours of 9 and 11 AM. During the latter hours, the lizards were reluctant to leave their basking site when disturbed. The basking site was usually beneath the branches of plants that allowed some sunlight to filter through to the soil. From about 12 noon to 4 PM, the lizards were somewhat inactive, remaining in the shade of plant cover (Fig. 6), at which time their body temperature varied from 33.0°C to 34.7°C. The corresponding ambient temperatures indicated an appreciable drop in temperature from sunlight to shade (Fig. 6) between 12 noon and 1 PM, followed by a steadily increasing temperature towards the hottest part of the day. The lizards were again active in and out of sunlight between the hours of 4 to 5 PM.

Three individuals were captured, marked with paint, and then removed from their home site for a distance of 600 meters. The place of release was three dunes and two depressions to the northeast of the homesite, a rabbitbush flagged with red cloth. All three lizards returned to their homesite within four days, one returned in three days, the other two in four. These lizards were observed to have a small home range within the dunes, seldom moving more than 10 meters from a particular plant. The experiment, although tried only once seems to indicate that these lizards have a decided tendency to remain within familiar cover, and have some powers of orientation.

The *Sceloporus undulatus cowlesi* population occupying the center of the gypsum dunes is distinguishable from *S. u. consobrinus* populations off the dune area only by color. Lowe and Norris (1956) indicated that the two populations were distinct from one another on the basis of color, color pattern, and amount of prefrontal contact. An examination of 15 specimens from the adjacent adobe soils, 15 from the edge of the gypsum dunes, and 85 from the center of the gypsum dunes reveals evidence of gene flow between the three samples. A comparison of the number of femoral pore series, and the width

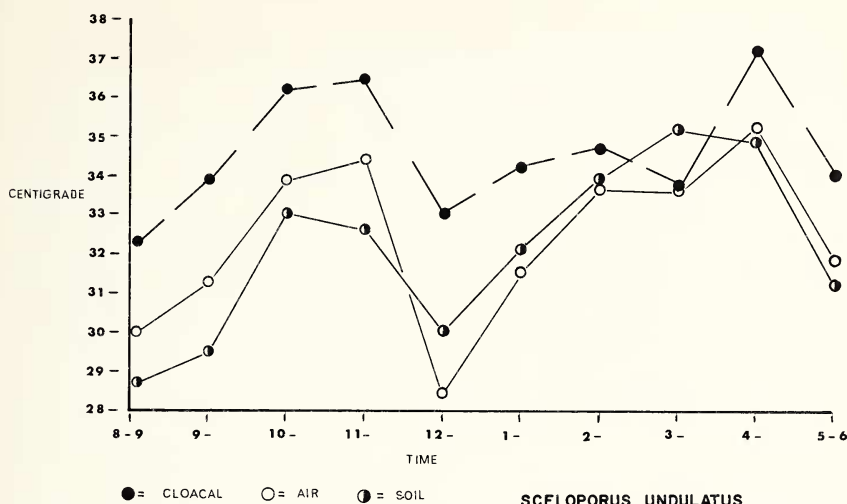


Figure 6. Vertical axis represents the average cloacal and ambient temperatures of *Sceloporus undulatus* on the White Sands during the summer months of 1963 to 1965, horizontal axis indicates hourly intervals during the same period. The drop in cloacal temperature between the hours of 12 and 2 indicates a period of inactivity in the shade of vegetation. The rise in cloacal temperature between the hours of 4 and 5 indicates a period of activity and basking prior to burrowing in the sand for the night.

of the mid-dorsal stripe are nearly identical in all three samples. The number of scales separating the lateral blue belly patches is ontogenetic, varying from 6 to 7 scales in specimens measuring 28 to 40 millimeters in snout-vent length, to 1 to 4 scales in specimens measuring 50 to 61 millimeters. The prefrontals are in contact with one another in 95 per cent of a sample of 23 individuals examined by Lowe and Norris (1956) from the White Sands. The amount of prefrontal contact is 37 per cent in the sample from the center of the dunes, 44 per cent in the edge of the dunes sample, and 36 per cent in the sample from the adjacent adobe soils. The latter two samples are small (15 each), but the larger series from the center of the dunes indicates a greater amount of non-contact of the prefrontals than found by Lowe and Norris (1956).

The color and color pattern of the sample from the center of the gypsum dunes are more variable than indicated by Lowe and Norris (1956). The ground color of male *S. undulatus cowlesi* is dirty gray to pale yellowish-white, with a light blue mid-dorsal stripe from the occiput to the tail. The lateral dark stripe is buff, the ventrolateral dark stripe dark gray. The belly patches are bright blue, bordered mid-ventrally with black edges. The throat patch is similar to the belly patch in color. The whitish ground color of the belly is immaculate, lacking the gray and grayish-black flecks found in individuals from the adobe soils. The female retains the basic color pattern of individ-

uals examined from adobe soils, but the ground color is more buff, with some light orange color on the top of the head, and a mid-dorsal stripe of light bluish-gray.

The ground color of the male *S. undulatus* occupying adobe soils is dark grayish-brown with a pair of dorsolateral gray stripes bordered above by a mid-dorsal grayish-brown stripe, whose intermargins are lined with a linear series of dark brown spots. The dorsolateral light stripe is bordered below by a dark brown stripe, that is in turn bordered below by light grayish-brown stripe that is bordered below by ground color. The belly is dirty white with scattered flecks of grayish or grayish-black. The lateral belly patches are bright blue, the inner margins edged with black. The throat patch is dark blue, outlined with black and united across the throat. Females are similar in color but lack the brightness of the belly and throat patches. The latter color areas are usually smaller and lack the black borders. The striping is more pronounced in the females and in addition to the mid-dorsal stripe, a series of whitish linear spots is present along its outer margins.

Individuals from the edge of the dunes are lighter in color than the adobe soil sample, but darker than those from the center of the dunes. The general ground color is light brown to buff with a lighter mid-dorsal stripe. Individuals examined from depressions between the dunes 1, 2, 3, 5, and 7 kilometers, respectively, towards the center of the dunes from the outer edge, reveal a progressively lighter ground color, especially within the first 3 kilometers. However, an occasional, relatively dark individual is found in the center of the dunes.

There is apparently more gene exchange between normal and pallid color populations than was formerly believed. This may be due to the movement of the dunes towards the northeast, capturing fresh areas of adobe soil that include normal colored individuals. These captured areas are generally extensive and may include areas up to 0.4 square kilometers.

The captured areas slowly fill in with gypsum sand, and slowly turn from dark brown soil to white soil. Light and medium dark specimens have been observed in various color stages in the captured areas.

The behavior of this species may tend to offset the selective pressure favoring the light color. These lizards tend to stay in plant cover, and 99 per cent of the plant cover is found in the depressions between the dunes, usually upon an adobe base encrusted with a gypsum-adobe mixture. The soil is usually buff to dirty gray in these areas, offsetting the brilliant whiteness of the surrounding dunes. The majority of the specimens were found in or beneath rabbitbush, mormon tea, sand bunchgrass, or on the trunks of yucca. These plants have grayish to brown bark, suggesting a selective pressure acting on the lizard population to retain brown pigment as a means of camouflage while associated with the plant cover. This selection pressure would be working counter to selection for light colors effective for travel from plant to plant.

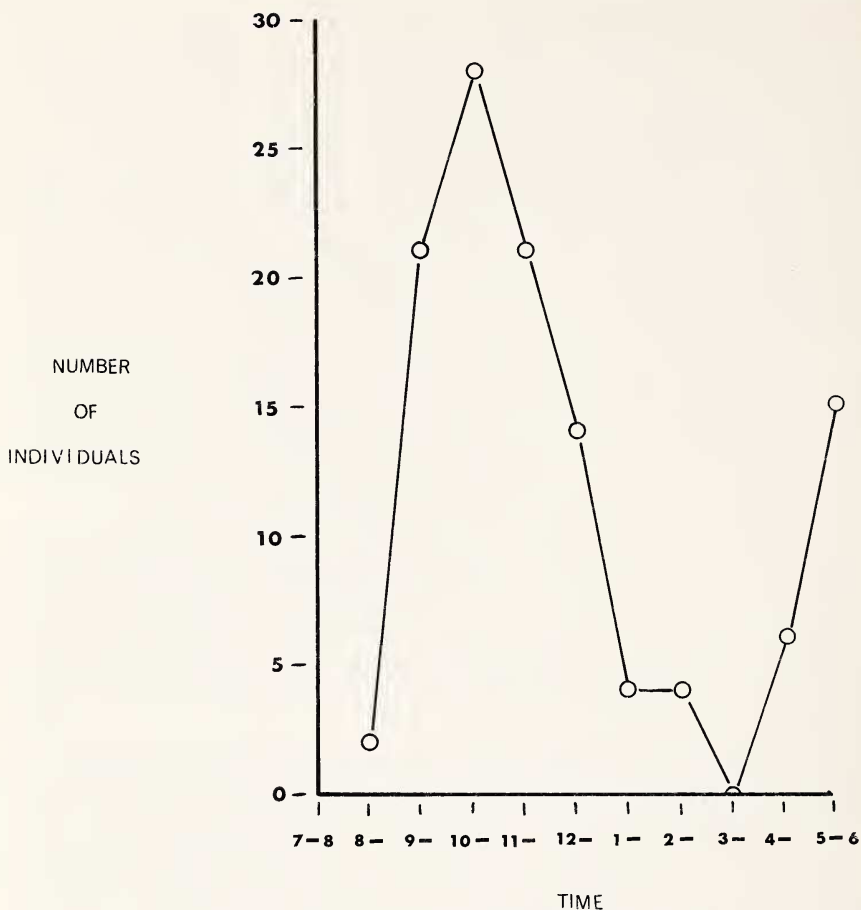
Holbrookia maculata: This arenicolous lizard is common on the dunes and in depressions between the dunes. It does not seem restricted to the immediate vicinity of plant cover as is *S. undulatus*. Several individuals were found beneath rabbitbush, mormon tea, and sand bunchgrass during the heat of the day, but their foraging activity seems to be in more open areas. Individuals could not be found in adobe soils adjacent to the gypsum dunes. The nearest known locality to the white sands of normal colored individuals is 24 kilometers south of Alamogordo. The latter area is composed of reddish quartz sand and lies some 29 airline kilometers southeast of the Monument. The population inhabiting the dunes appears to be restricted to the central dune area. None was seen within 3.2 kilometers of the edge of the dunes.

Both sexes appear to be active at the same time. However, there seemed to be a third more males present in the population during June and July, with females becoming slightly more numerous than males in August. Their greatest activity period was observed to be between 9 AM and 12 noon, when the soil temperature ranged from 32 to 36°C. [On a day to day tally, greater numbers were always observed during the latter period (Fig. 7).]

As in *S. undulatus*, there appears to be a period of inactivity between 2 and 4 PM, at which time the soil temperature reaches about 40°C. Individuals were observed burrowing in the surface sand of the dunes when the soil temperature reached 40°C. They reappeared about 4 PM when the soil temperature was approximately 38°C but dropping. Individuals remained active beneath dense clumps of rabbitbush until about 6 PM, when the soil temperature beneath the shrubs had dropped to 33°C.

Gravid females were observed in June and July, with the deposition of eggs occurring over an 8-day period, July 8 to the 16th (1963). Females revealed bright colors on the hind limbs, sides of the body, and top of the head during the last week of June. The colors began as light lemon yellow and turned progressively darker and brighter (yellow to orange) through the first week of July. The top of the head became bright yellow to orange in some females just prior to egg deposition. All females captured for obtaining body temperatures on July 16 had deposited their eggs and the bright colors of the head, body, and limbs were fading to a washed-out yellow. By July 27, the colors were no longer obvious. Hatchlings were seen for the first time on August 17, and became progressively more abundant through early September.

Body temperatures and associated ambient temperatures were obtained on 176 individuals, including all sexes and ages, during June, July, and August. The body temperature was always above that for the air and ground (Fig. 8). The majority of the body temperatures were taken when the lizards were most abundant (9 to 11 AM). Many were observed basking during the latter period. This species began seeking shade at about 11 AM, when the soil temperature reached 36 to 38°C. The lizards continued to be active in and around vegetative cover until the soil temperature reached approximately 40°C.



HOLBROOKIA MACULATA

Figure 7. Vertical axis represents the average number of individuals of *Holbrookia maculata* observed each hour on the White Sands during the summer months of 1963 to 1965, horizontal axis indicates hourly intervals during the same period.

The white sands earless lizards, *H. m. ruthveni*, was described as a distinct form by Smith in 1943. His description of the form indicated that squamation was similar in all the samples examined, but color alone would separate the white sands form from all others (principally the closest race, *H. maculata flavilenta*).

An examination of 160 specimens from the white sands and 50 normal colored individuals from southern New Mexico indicates a much closer rela-

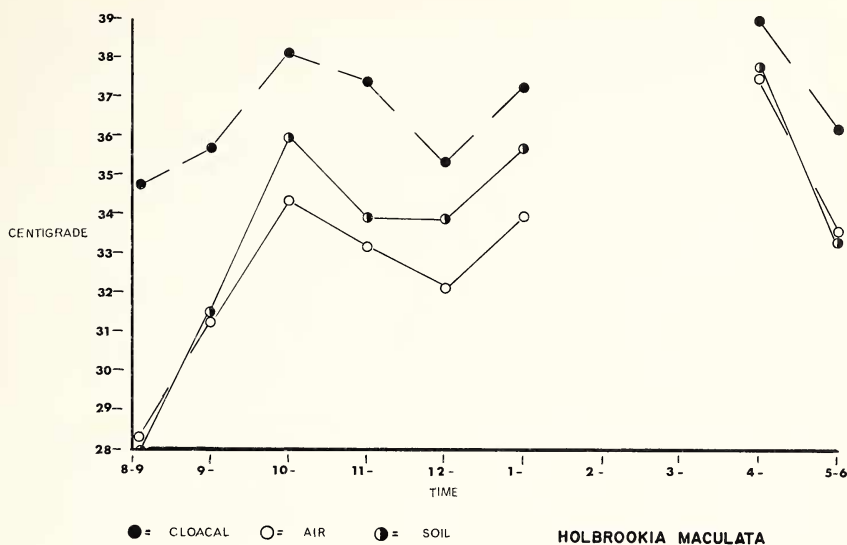


Figure 8. Vertical axis represents the average cloacal and ambient temperatures of *Holbrookia maculata* on the White Sands during the summer months of 1963 to 1965, horizontal axis indicates the hourly intervals during the same period. The drop in cloacal temperature between the hours of 12 and 1 indicates a period of rest in the shade. The absence of cloacal temperatures between the hours of 2 and 4 indicates the period of rest beneath the surface of the sand. The temperature between the hours of 4 and 6 indicates a period of activity prior to burrowing beneath the sand for the night.

tionship between the populations. In white sands males, the variation in ground color ranges from dark bluish-gray to light yellowish-white. A dorsal pattern of two dorsolateral linear series of small blackish spots from the rear of the head to the base of the tail is present in 90 per cent of the sample. In addition, a series of small white spots is scattered over the sides of the body, varying in intensity with the type of ground color of each specimen. The mid-dorsal area is pale bluish to bluish-white, lacking spots of any kind in most specimens. Occasionally, white spots may be present in some individuals.

Normal colored males of *H. m. flavilenta* have a ground color of light to dark brown with the dorsolateral series of black spots forming a series of chevrons that continue from the ear of the head on to the proximal one-third of the tail. The lateral white spots are present, but larger and less numerous than in the White Sands sample. The mid-dorsal area is bluish-gray to brown. The brown barring of the limbs is distinct, much less so in the white sands sample.

White sands females exhibit dorsal colors and color pattern similar to

the males, but with less white spotting. One female is almost normal colored, with distinct chevrons on the dorsum and dark flanks. The opposite extreme is also obtained, with the near absence of any dorsal pattern of any kind in some individuals.

It appears that the white sands population has retained some of the genes necessary to produce dark individuals. The majority of the samples examined were light colored, but enough darker individuals were present to cast doubt upon the validity of recognizing all white populations of lizards.

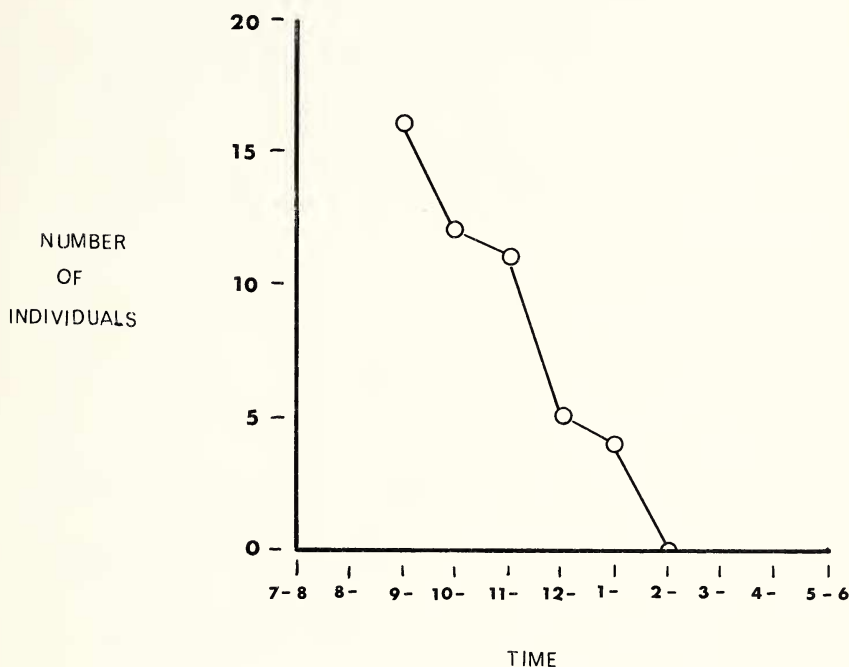
Males were observed fighting with one another on several occasions in June. Biting, tail thrashing, pursuit, and normal bluff display (see Clarke, 1965, for details of combat and display in *Holbrookia*) were used by the males. During the mid-morning period male *Holbrookia* often stationed themselves on an elevated area near the base of sand verbena or sand bunchgrass. From the latter vantage point they were observed in challenge displays. Males were seen in companionship with females on several occasions but copulation was not observed. During late morning hours males appeared to wander about more than females. The majority of females were found near vegetation during their activity periods, while males were found traversing large dunes some distance from plant cover. Usually when the tracks of *Holbrookia* were followed across the open dunes to the point where they buried themselves in the sand, the individual extracted from the sand was a male, except on one occasion.

Cnemidophorus inornatus: The inornate whiptail lizard is abundant throughout the depressions between the dunes, along the edge of the dunes, and was seen as far as 50 meters from the dunes in adobe soil. *C. neomexicanus* was the only other whiptail seen beyond the fringes of the dunes. The latter species also occurs in the stabilized dunes along the southwest edge of the Monument. *C. inornatus* seems to be most abundant in the depressions between the dunes where there is a considerable amount of sand bunchgrass, yucca, and rabbitbush. Low dunes that were partly covered with vegetation were frequently utilized by the lizards. A few were seen traversing the large dunes that were void of vegetation.

The sex ratio of the sample varied little over the three month summer period. Females represented 55 per cent of the sample in June, 38 per cent in July, and 45 per cent in August. Both sexes appeared to be equally active between 9 and 10 AM, with the largest numbers observed at that time. This species seldom appeared upon the surface of the white sands before 9 AM, while the population on the adjacent adobe soil was active about 8 AM. There was a definite lag (about an hour) in soil temperature between the adobe and gypsum soils during the morning hours. The adobe soil reached 33°C at approximately 8 AM, while the gypsum soil did not reach this temperature until approximately 9 AM.

As the soil temperature of the dunes reaches 33°C, the lizards become

active almost immediately. They appeared in large numbers (Fig. 9) during the first hour after their emergence from their burrows, but the numbers began to dwindle after an hour or two following their first appearance, and none was seen after 2 PM, unless the weather was extremely cool following a rain. Those individuals observed on the adobe soil disappeared at approximately 11:30 AM when the soil temperature was between 49 and 51°C.



CNEMIDOPHORUS INORNATUS

Figure 9. Vertical axis represents the average number of individuals of *Cnemidophorus inornatus* observed each hour on the White Sands during the summer months of 1963 to 1965, horizontal axis indicates hourly intervals during the same period.

Gravid females were observed during late June and July, but hatchlings were not seen until the latter part of August (31st). The females of this species apparently carry the eggs for a longer period of time, or the incubation period is longer. Medica (*In press*) indicated an incubation period of 46 days for *C. inornatus* from the vicinity of Las Cruces, New Mexico. In any case, the young of this species appear later during the summer than the young of *Hol-*

brookia and *Sceloporus*. Color change in females before and after egg deposition was not observed in this species.

Body and ambient temperatures were obtained on 84 individuals of this species. The body temperature always appeared to be 3 to 4°C above that recorded for the air and soil (Fig. 10). Most individuals were found foraging about plant cover when they were obtained for body temperatures. Most individuals were observed in direct sunlight during their foraging period, but prior to their subsequent disappearance into burrows, they were seen resting in the shade of vegetation. At the onset of the latter period, this species became very wary and sought burrows when approached. Several body temperatures were obtained from individuals while in their burrows in late afternoon. The lizard burrows were found approximately 10 to 15 centimeters below the surface at the base of sand bunchgrass, yucca, and rabbitbush. The body temperature of these lizards was approximately 2°C above that of the surrounding soil.

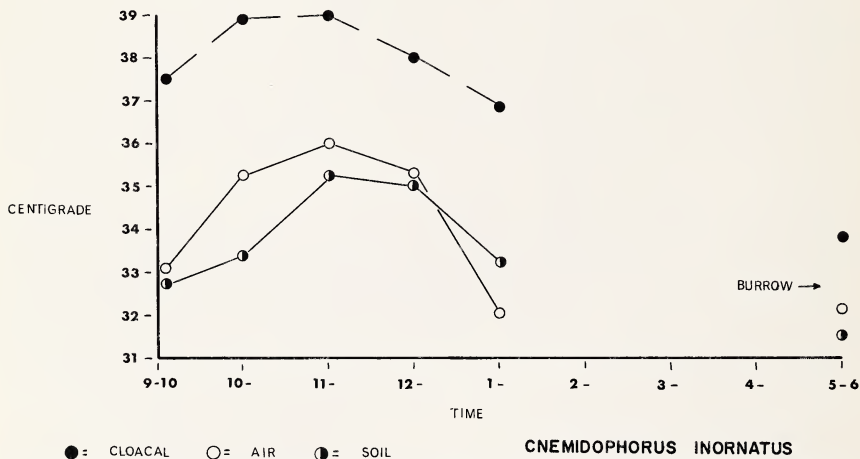


Figure 10. Vertical axis represents the average cloacal and ambient temperatures of *Cnemidophorus inornatus* on the White Sands during the summer months of 1963 to 1965, horizontal axis indicates hourly intervals during the same period. The absence of temperature data between the hours of 2 and 6 indicates a period of rest beneath the sand surface. The indicated burrow temperature represents 3 individuals taken from burrows on three different occasions.

The color of *C. inornatus* from the central part of the dunes is strikingly different from typical normal colored samples from southern New Mexico. The mid-dorsal light stripe is absent in about 25 per cent of the sample. The ground color is pale yellowish-gray to pale bluish-gray with the 6 to 7 light stripes present but somewhat obscure. The limbs are pale blue without a

suffusion of grayish bars on the dorsal surfaces in most specimens. The head is light brown to gray-blue in females, bright sky-blue to blue in males.

The ground color of a sample taken 20 meters from the dunes is light grayish-brown to brown, with 7 white lines distinct in all specimens. Specimens taken from the edge of the dunes are much lighter in color than those taken 20 meters into the adobe soil, but appear to be intermediate between those off the dunes and those in the center of the dunes. However, those from the edge of the dunes lack the suffused grayish bars on the upper surfaces of the limbs that are present in those on the adobe soils. A sample of 200 individuals from the vicinity of Las Cruces has a ground color of dark brown to chocolate brown with the 7 white lines greatly contrasting against the dark ground color. Two individuals of this color type were found within 50 meters of the dunes. However, an occasional individual is found in the central area of the dunes that is slightly darker than its lighter counterpart, indicating a possibility of some gene exchange with normal colored populations, or a retention of some genes for darker color.

Males were observed fighting with other males throughout the summer. In some instances the fighting pairs were not collected and sex could not be determined. The fight consisted of a bluff display, followed by pursuit, biting, and tail thrashing. Males were observed following females in July, but the females often turned and pursued the males for a short distance. Copulation was not observed in this species. Both males and females seemed to wander aimlessly over a large area. One male was followed for approximately 30 linear meters. Fighting usually occurred when the paths of two lizards crossed one another at the same time.

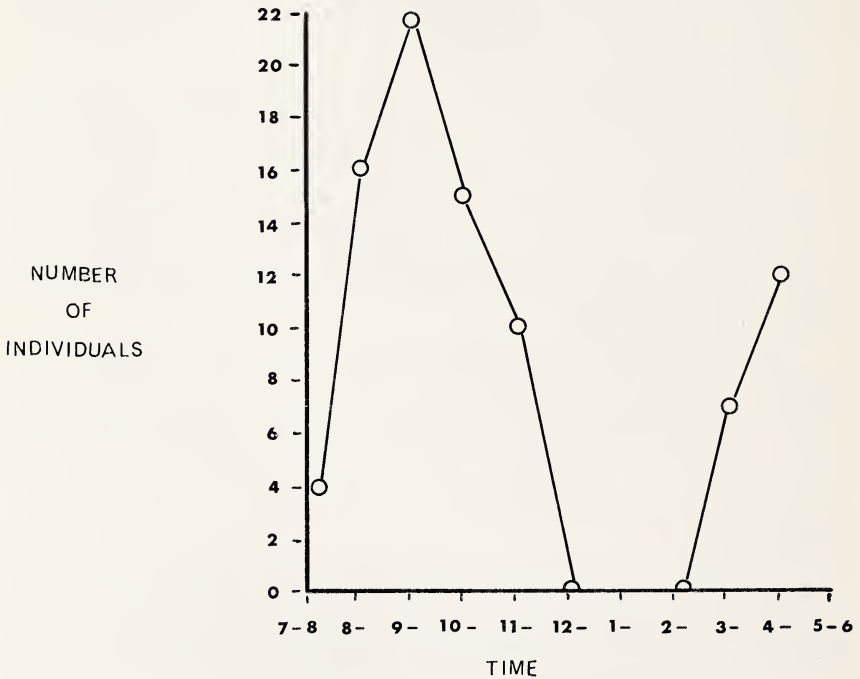
The majority of the burrows occupied by this species appeared to be those also occupied by the tenebrionid beetle, *Eleodes* sp. It is not known whether the beetle or lizard digs the burrow. In some instances, the burrows utilized were obviously those of *Perognathus apache gypsi*. One whiptail was found in a burrow of the pocket gopher, *Geomys arenarius*. Occasionally an individual of *S. undulatus* was found in a burrow with *C. inornatus* and tenebrionid beetles.

Uta stansburiana: The side-blotched lizard is common on the adobe soils surrounding the white sands, but has never been observed for more than 30 meters into the dunes. It has been taken in association with *Sceloporus undulatus*, *S. magister*, *Crotaphytus collaris*, *Cnemidophorus neomexicanus* and *C. inornatus* on the adobe soils, and with *S. undulatus* and *C. inornatus* along the edge of the dunes. Smith (1943) indicated that *Uta* occur commonly on the dunes with *S. undulatus* and *H. maculata*, but we have been unable to find *Uta* anywhere in the dunes beyond 30 meters. Ruthven (1907) indicated that he did not find *Uta* anywhere in the white sands except on the outer edge of the dunes.

Very few *Uta* were taken in open areas between vegetative cover on the

peripheral dunes. The majority of specimens were obtained beneath the foliage of squawbush (*Rhus trilobata*) and pennyroyal (*Poliomenantha incana*), both of which form dense ground cover. *Uta* were found associated with tar bush (*Flourensia* sp.), creosote bush (*Larrea tridentata*), burrograss (*Scleropogon* sp.), and gramma grass (*Bouteloua* sp.) on the adobe soils.

Both sexes were active from approximately 7 AM to 12 noon. The lizards spent the remainder of the day in dense shade and in rodent burrows. The majority of individuals were observed between 8 and 11 AM, with their numbers decreasing gradually until the soil temperature reached 50°C+ in open sunlight on adobe soils, and 40°C+ on the edge of the dunes (Fig. 11). A few sporadic observations were made on *Uta* in the afternoon on the adobe soils. The area surrounding the dunes becomes unbearably hot from noon to about 4:30 PM, making continuous observations difficult.



UTA STANSBURIANA

Figure 11. Vertical axis represents the average number of individuals of *Uta stansburiana* observed each hour along the edge of the White Sands during the summer months of 1963 to 1965, horizontal axis indicates hourly intervals during the same period. The absence of individuals between the hours of 12 and 3 is probably due to inadequate observations during this period.

Gravid females were observed in mid-June and mid-July, with hatchlings present in the population on July 23 and August 25. The latter observations lend support to Tinkle's (1961) study that mature females may have as many as three clutches of eggs per year (reproductive season).

The body temperature of 40 individuals of *Uta* from the adobe soils is higher than the air temperature, but much lower than the soil temperature (Fig. 12). The soil temperature increased at a rapid rate between 10 AM and 12 noon, and the density of *Uta* was noticeably less after the soil temperature reached 39°C. *Uta* appeared to be active on the adobe soils from 7:30 AM (soil temperature 36°C) to 10 AM (soil temperature 43°C and rising rapidly).

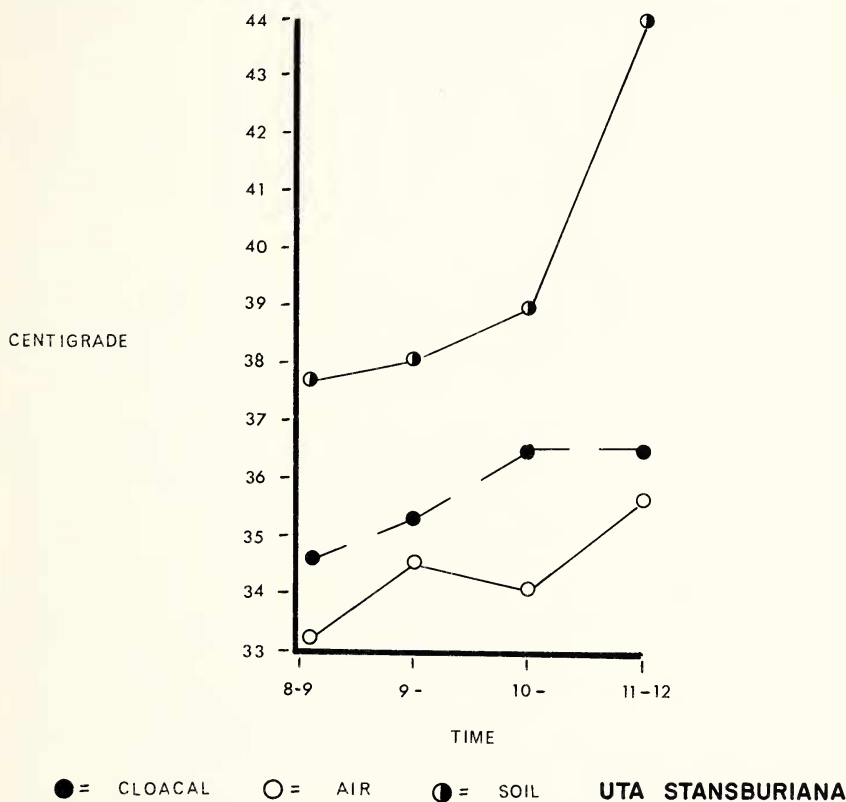


Figure 12. Vertical axis represents the average cloacal and ambient temperatures of *Uta stansburiana* along the edge of the White Sands during the summer months of 1963 to 1965, horizontal axis indicates hourly intervals during the same period. The absence of temperature data for the afternoon period is due to inadequate sampling during this period. Note the high soil and low cloacal temperatures during the morning hours.

They were observed feeding, basking, and presenting territorial displays during the latter period.

The ground color of individuals on the gypsum dunes and on the adobe soils is similar. The small sample from the edge of the dunes is slightly lighter in color, but the basic color and color pattern are identical to the sample obtained from the adobe soils.

DISCUSSION

Each of the four species of lizards found within the immediate vicinity of the White Sands of New Mexico shows a distinctive evolutionary mode. Each species has adapted to the white environment in a slightly different fashion as an interaction between the forces of genetic materials and natural selection.

The dunes population of *Sceloporus undulatus* appears to have some gene flow with its parental population on the adobe soil. Individuals found along the fringes of the dunes are intermediate in color and color pattern between the dunes and adobe soil populations. Occasionally a dark individual is found well within the confines of the dunes and a light individual near the edge of the dunes on adobe soil.

The presence of dark colored individuals is probably due to the behavior of the species. *S. undulatus* is associated with dense shrubby vegetation. Selection for cryptic coloration probably favors the survival of dark individuals living in close association with vegetation. This is evident in the adobe soil population. The survival of individuals foraging for food on dark soils and traversing open areas in search of food and sexual companionship is enhanced by dark coloration. The white gypsum soil population is, in effect, being challenged by two opposing selective pressures: pressure favoring dark pigment associated with the microenvironment of conditions within the clumps of vegetation; pressure favoring light pigment, an adaption to the white soil macroenvironment. The latter selective pressure appears to be over-riding the selection for dark pigment on the dunes, but both pressures are still acting on the population. The few dark individuals present on the dunes are probably being selected against, but a behavior pattern of close association with the vegetation is apparently advantageous to the population, regardless of color. Eventually, the dunes population should reach an equilibrium, combining a minimum selection for dark color associated with the vegetation, and a maximum selection for the white macroenvironment.

Representatives of the dark soil counterpart to the gypsum dune population are seemingly able to wander into the dunes without being heavily preyed upon because of their association with the vegetation. Thus gene exchange between the dunes population and the dark soil counterpart does not seem to be greatly restricted at this time. The two populations probably represent ecological races in the sense of Grant (1963).

The dunes population of *Cnemidophorus inornatus* appears to have restricted gene exchange with the population on the adobe soil. The individuals sampled from the edge of the dunes are intermediate in color and color pattern between the dunes and adobe soil populations. This zone of intermediacy is narrow and occupies a belt of mixed adobe and gypsum soils from 1 to 10 meters in width along the edge of the dunes. The boundaries of the latter soil belt are abruptly demarcated, somewhat tan in the middle, but rapidly grading into dark brown adobe soil and white gypsum soil on either side.

The dunes population is very light colored with the dark stripes obscure in most specimens. Unlike *S. undulatus* this species requires open areas for foraging, between clumps of vegetation and on the bare slopes of the dunes. The absence of dark individuals on the gypsum soil indicates a strong selection for light pigment.

The population occupying the intermediate zone may represent a deme or a narrow zone of restricted gene flow between the parental stock and the paternal offspring. The latter is more likely because of the narrow width of the intermediate zone and the close proximity of light and dark individuals on either side of the zone. The two totally different environments probably enforce the restriction of gene flow at the present time and allow only intermediates to survive out of each clutch of eggs from a cross between dark and light colored individuals. According to Grant's (1963) classification of population systems, the two populations may represent contiguous allopatric races.

The dunes population of *Holbrookia maculata* seems to be completely isolated from its dark soil counterpart. No evidence of gene exchange between the dunes population and the population found on the reddish quartz sands near the gypsum dunes has been found. One intermediate colored individual was found in the center of the dunes. The dunes population may have reached the final stages of speciation where almost all individuals are white with an occasional darker individual appearing in a clutch as a remnant of the original gene pool. If this is the case, the white sands *Holbrookia* population may represent an allopatric semi-species as defined by Grant (1963). However, without genetic compatability studies the status of the dunes population will remain in doubt.

The evolutionary history of the *Uta stansburiana* populations from the vicinity of the White Sands is uncertain. *Uta* have not successfully invaded the dunes for an appreciable distance. *Uta* occur in the intermediate zone (adobe-gypsum soil mixture) and slightly beyond in more stabilized dunes. Three possible reasons for the absence of *Uta* in the major portion of the dunes are: (1) other species invaded first and filled the available niche, (2) *Uta* invaded the dunes along with the other species but could not maintain itself due to the absence of enough food and shelter (competition with the other species), (3) *Uta* is genetically unable to adapt to the white soil environment.

ACKNOWLEDGMENTS

I wish to thank the personnel of the White Sands National Monument for their cooperation while the author was a collaborator for the Monument from 1963 to 1965. My heartfelt thanks go to Philip A. Medica, Walter and Joan Conley, and Mike and Judy Rubick who spent many hours toiling in the dunes with me. I thank the Society of Sigma Xi Grants-in-Aid of Research committee for funds for summer field work in the white sands during 1963 and W. Ronald Heyer, Robert J. Lavenberg, Dr. Charles H. Lowe, Jr., and Dr. Jay M. Savage for critically reading the manuscript.

LITERATURE CITED

- Benson, S. B.
1933. Concealing coloration among some desert rodents of the southwestern United States. U. Calif. Publ. Zool., 40(1):1-70.
- Bugbee, R. E.
1942. Notes on animal occurrence and activity in the White Sands National Monument, New Mexico. Trans. Kansas Acad. Sci., 45(42):315-321.
- Clarke, R. F.
1965. An ethnological study of the iguanid lizard genera *Callisaurus*, *Cophosaurus*, and *Holbrookia*. Emporia State Res. Stud., 13(4):1-66.
- Dixon, J. R., and P. A. Medica
1966. Summer food of four species of lizards from the vicinity of White Sands, New Mexico. Los Angeles County Mus., Cont. in Sci., 121:1-6.
- Emerson, F. W.
1935. Ecological reconnaissance in the White Sands, New Mexico. Ecology, 16(2):226-233.
- Grant, V.
1963. The origin of adaptations. New York: Columbia Univ. Press, v+606 p.
- Herrick, C. L.
1904. Lake Otero, an ancient salt lake basin in southeastern New Mexico. Amer. Geol., 34:174-189.
- Lowe, C. H., and K. S. Norris
1956. A subspecies of the lizard *Sceloporus undulatus* from the White Sands of New Mexico. Herpetologica, 12(2):125-127.
- Medica, P. A.
In press. Food habits, habitat preference, reproduction, and diurnal activity in four sympatric species of whiptail lizards. (*Cnemidophorus*) in South Central New Mexico. Bull. So. Calif. Acad. Sci., 66.
- Ruthven, A. G.
1907. A collection of reptiles and amphibians from southern New Mexico and Arizona. Bull. Amer. Mus. Nat. Hist., 23:483-604.
- Smith, H. M.
1943. The white sands earless lizard. Field Mus. Nat. Hist., Zool. Ser., 24(30):339-344.
- Tinkle, D. W.
1961. Population structure and reproduction in the lizard *Uta stansburiana stejnegeri*. Amer. Midl. Nat., 66(1):206-234.